TechData Sheet

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Occupancy Sensors

Occupancy sensors secure power to the lights in unoccupied spaces to conserve energy. This TechData Sheet presents occupancy sensor types, applications, and the potential economic savings of retrofit projects. Manufacturers of occupancy sensors claim energy savings of 5 to 75 percent. Actual savings will vary greatly depending on the amount of light being controlled and the occupancy pattern in the room. Spaces that show the greatest energy conservation from occupancy sensors are: restrooms, lunch or break rooms, conference rooms, coffee messes, and copy rooms.

TECHNICAL DESCRIPTION

The two most common types of occupancy sensors are ***passive infrared*** and ***ultrasonic***. Microwave technologies are available, but are intended for use in the security and alarm industries. Indirect motion sensors, such as those tripped by a foot pad or audible noise, are for use in special applications, and will not be addressed here. Some manufacturers offer hybrid sensors that combine both infrared and ultrasonic capabilities in the same unit, offering improved operation with a minimum of false triggering.

Occupancy sensors are composed of four main components: motion detector, electronic control unit or controller, relay, and power supply. The motion detector uses either ultrasonic waves or infrared radiation for sensing motion. The electronic control unit uses the information sent from the motion detector to determine the occupancy status of the room. Output from the controller opens and closes a relay, which controls power to the lights. A DC power supply provides power to the controller.

Not all types of lighting can be effectively controlled with sensors. Fluorescent and incandescent lighting are well suited to sensor control. High intensity discharge (HID) lighting, however, may pose problems for sensors. HID lighting, such as high pressure sodium and mercury vapor, needs to cool down before it can be relit. Once the lamp arc is restruck, the pressure and temperature in the arc tube will have to rise to normal operating levels before full light output is reached. In the case of metal halide this cool down and warm-up process could take 15 minutes, which may be unacceptable for occupants. Also, HID equipment, unlike fluorescent lighting, is not well suited to frequent cycling. Cycling these fixtures too often can significantly shorten the lamp life. Fluorescent lamps are also subject to the same life shortening but their low cost makes the energy savings outweigh the cost of the reduced life span. This is not true for the HID lamps, since they are comparatively expensive and less resistant to degradation brought on by frequent cycling.

Compact fluorescent (CF) lamps also pose a problem for sensors. Studies have shown that CF lamps are particularly sensitive to frequent cycling. This, in combination with their high cost per watt, makes CF lamps poor candidates for occupancy sensor control.

Passive Infrared (PIR) Sensors

Passive infrared sensors respond to the infrared (IR) heat energy emitted by people. They are passive because they do not emit radiation, they only detect it. The PIR sensor detects motion by sensing temperature change over time. PIR sensors are line of sight devices which means they cannot "see" around corners or through partitions. Infrared radiation is detected by a pyroelectric transducer. The lens surrounds the sensing transducer and focuses heat energy onto the detector. A lens views an area with an array of narrow and discrete beams or cones. When there is motion in a space across the cones of vision, a positive signal is generated and sent to the controller. Slow movement is difficult to detect. The movement of large masses of heated air may cause a false positive reading.

Because of the fan-shaped detection pattern of the PIR sensors, coverage gaps occur between the cones of vision of alternate segments of the lens. The gaps widen with distance. A coverage gap of 8 feet occurs at a distance of 40 feet from the sensor. The sensitivity of the sensor decreases with distance from the sensor because the sensor is most sensitive on

movement between the cones. Average sensitivity ranges are shown in Table 1. The sensitivity of PIR sensors can vary greatly with product quality and electronic circuit design.

Table 1
Sensitivity of Passive Infrared Sensors

Sensitivity	Distance from Sensor
Hand motion	Up to 10 feet
Arm and upper torso motion	10 to 20 feet
Full body motion	20 to 40 feet

An essential component of this system is the time delay. The adjustable delay keeps the sensor from turning off the lights during short periods when the space is occupied but there is no motion. Each space will have its own optimum setting which is best determined by observation.

PIR sensors do not have to be in enclosed spaces to work well. They are often put in large areas where there are no obstructions. A PIR sensor can also filter out signals from unwanted areas by masking. The lens which detects the IR signal can be partially covered to avoid picking up signals from unwanted areas. This is particularly useful when mounting a PIR sensor near a doorway.

Ultrasonic Sensors

Ultrasonic sensors emit an ultrasonic wave that saturates the space. Changes in the wave are detected by the sensor which sends a positive signal to the controller. Ultrasonic technology is well suited to an enclosed space such as a conference room or lunch room, because the waves must be contained within the space. This technology can also be applied to areas with partitions because the waves can saturate the areas behind them. Recent tests showed that the waves can cover areas behind hard partitions well, like in bathrooms. However, in areas with cloth-covered partitions, such as open office spaces, the sensors did not detect motion in the obstructed areas.

Because this technology detects any movement large enough, false readings can occur due to movements of large volumes of air by HVAC systems or fans. Also, ultrasonic sensors cannot be effectively masked like PIR sensors. This being the case, they are subject to false triggering from outside the control area.

Both PIR and ultrasonic sensors can be installed as wall switches or on ceiling mounts. The wall mount switches are the simplest to install because they replace the existing wall switch. Ceiling-mount versions require more labor to install, but provide greater flexibility. When several ceiling-mounted ultrasonic sensors are used together with additional relays, they can control a large number of lighting fixtures in a large area. Table 2 shows the average sensitivity distances for ultrasonic sensors.

Table 2
Sensitivity of Ultrasonic Sensors

Sensitivity	Distance from Sensor
Hand motion	Up to 25 feet
Arm and upper torso motion	Up to 30 feet
Full body motion	Up to 40 feet

As mentioned previously, the two technologies are now being combined to allow for the maximum coverage and the fewest false readings. Table 3 summarizes the costs, coverage, and features of the two types of sensors.

Occupancy Sensor and Site Selection

Identifying a good application for an occupancy sensor and choosing the best type can be a difficult process. A survey technique could be as follows:

- Identify a space with erratic occupancy
- Note the type of light fixture
- Record the number of watts that need to be controlled
- Record the presence and use of partitions or other obstructions
- Note whether the space is enclosed
- Note the nature of movement in the space (i.e., large body movements etc.)
- Look for sources of false triggering (fans, robotics, etc.)

With this information and the flow chart included as Figure 1, the selection process can be greatly simplified. Note that the flow chart includes microwave technology as an option. Microwave sensors are not covered here due to their relatively high cost, which prevents them from being cost effective as an energy conservation technology.

When choosing an occupancy sensor, it is important to consider the amount of watts controlled by the sensor. Some manufacturers provide heavy duty wall switch units that can control up to 1,800 watts. This is probably the maximum amount of lighting that would be within the coverage area of the sensor. There are also multiple circuit units that control several circuits from one sensor, thus boosting the wattage control capacity per unit significantly. The use of this extended wattage control

Table 3
Comparison of Ultrasonic and Infrared Sensors

Unit Type	Coverage Range	Price Range	Characteristics
Ultrasonic Wall Switch Replacement	Up to ≅1,000 ft^2	\$40 - \$80	Best in smaller enclosed spaces such as break rooms; particularly good in spaces with partitions, such as small restrooms; can be falsely triggered by air movements.
Infrared Wall Switch Replacement	Up to ≅ 1,000 ft^2	\$30 - \$90	Best in smaller enclosed spaces such as break rooms and small restrooms; where full room is viewed by switch; where lens can be masked to avoid false triggering. Not good in spaces with partitions, such as restrooms.
Ultrasonic Ceiling Mount	Up to ≅ 2,000 ft^2	\$50 - \$100	Similar to ultrasonic wall switch unit, but with larger coverage and control capability; can be placed in any ceiling location.
Infrared Ceiling Mount	Up to ≅ 2,000 ft^2	\$50 - \$100	Similar to infrared wall switch unit, but with larger coverage and control capability; can be placed to read over short partitions.

is still limited by the coverage area of the unit. Sensors should first be sized by their range then by wattage capacity.

Choosing a site should be a logical process. It is wise to start with room types that are typically good applications for sensors. The following is a list of the most common room types that offer good savings potential. The rooms are listed in order of greatest potential.

- Bathrooms
- Break Rooms
- Copy Rooms
- Small Offices

ECONOMICS

It is difficult to generalize what the payback will be for an occupancy sensor project because there are so many parameters. The factors affecting cost effectiveness are:

- Installed cost (determined by sensor type)
- Hours saved per year
- Watts controlled by sensor
- Energy Charge (\$/kWh)
- Demand Charge (\$/kW)

Manufacturers usually list ranges of hours saved by room type. There are few independent data sources of lighted, unoccupied hours or hours saved per year available. Although it may be time consuming, it is preferable to estimate hours saved by observation. Project submittals should include some explanation of the source of the hours saved per year number. A study done by Pacific Northwest Labs yielded some lighted, unoccupied hours data. The data in Table 4 are based on this study, the numbers represent the lower end of the range. The data are based on a limited number of samples and should not be assumed for all cases. In the absence of observed data, the list can be used as a guide for determining potential savings. As mentioned earlier, the hours saved can change by adjusting the sensor's time delay.

Table 4
Lighted Unoccupied Hours by Room Type

Type of Room	Number of Samples	Hours Saved per Year
Restroom	10	1,800
Break Room	13	1,000
Copy Room	9	1,400

It should also be noted that there are exceptions to these hours. For example, in 24-hour operations the savings could be much higher. Also, at some facilities it has been observed that it is not common practice to turn lights off in some spaces at night. If overnight savings is included, the numbers in Table 4 could be significantly higher.

It is a common myth that sensors are not cost effective because they shorten lamp life and end up costing more than they save. This was probably true of older fluorescent lamps. Although it varies from model to model, the time a lamp needs

to be off to save money is rarely more than a couple of minutes. With lower prices and higher quality, newer fluorescent lamps allow for cost effective sensor control.

NFESC has developed a simple spreadsheet that calculates the simple payback for occupancy sensor projects. Output from it is shown in Table 5. The required inputs are electric rate and installed cost. Since it is almost impossible to tell how many occupancy sensors will have lights turned off during the monthly peak, demand savings is not included. The additional savings when demand is included is not significant.

If you would like a copy of this spreadsheet or more information on occupancy sensors contact: ***Mr. Art Leitherer at (805) 982-9594, DSN 551-9594, or aleithe@nfesc.navy.mil, or Mr. Mike Rocha at (805) 982-3597, DSN 551-3597, or mrocha@nfesc.navy.mil.***

Table 5
Spreadsheet Payback Calculations

Watts Controlled	Hours Saved	Simple Payback
300	2,000	3.28
	1,800	3.64
	1,400	4.68
	1,000	6.56
	600	10.93
	300	21.85
600	2,000	1.64
	1,800	1.82
	1,400	2.34
	1,000	3.28
	600	5.46
	300	6.56
1,000	2,000	0.98
	1,800	1.09
	1,400	1.40
	1,000	1.97
	600	3.28
	300	6.56
1,800	2,000	0.82
	1,800	0.91
	1,400	1.17
	1,000	1.64
	600	2.73
	300	5.46

$/kWh = 0.06
Installed Cost = 100

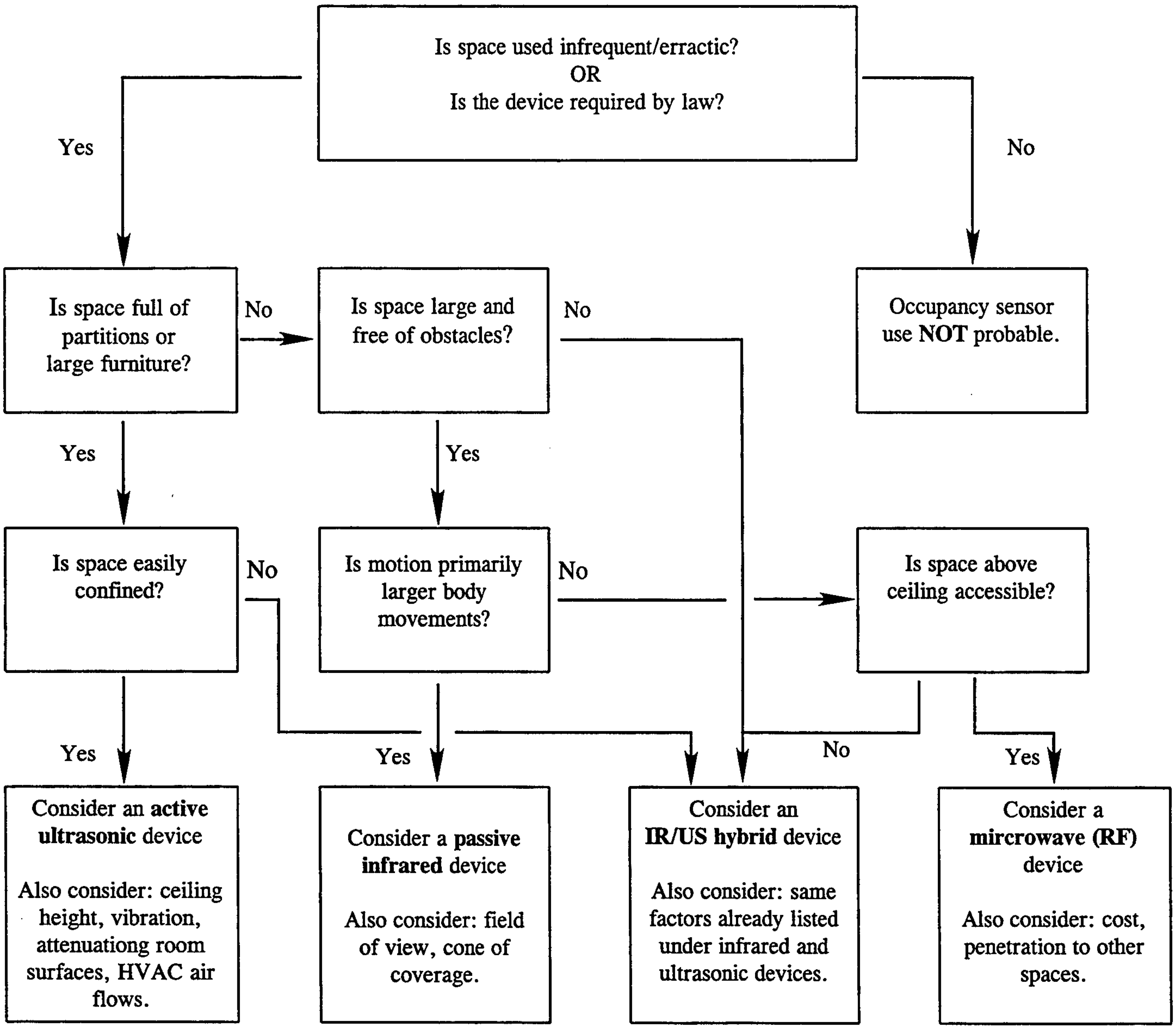

Figure 1. Occupancy sensor selection flowchart.

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